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A Suggestion for the Correction of Salinity Data Obtained with the S-T-D Instrument

by

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Director

A SUGGESTION FOR THE CORRECTION OF SALINITY DATA
OBTAINED WITH THE S-T-D INSTRUMENT

Anyone who has compared titrated salinity samples with the results of automatic devices which measure salinity or conductivity of sea water electronically, has been aware of inadequacies in the application of a constant correction to the data. The purpose of this article is to demonstrate a type of correction which varies according to temperature and salinity. This correction is easily applied to data obtained with the Salinity-Temperature-Depth instrument (Jacobson, 1948). By this means, reconciliation of STD data with corresponding salinity samples has been accomplished with marked success for a wide range of conditions and stringency in the region about Delaware Bay.

Certain difficulties in the reconciliation of STD data with independent observations may be ascribed to maladjustment or misalignment of the mechanical linkage between the temperature circuit and the salinity computing circuit. This fault may not be readily apparent unless fairly wide ranges of salinity and temperature are encountered. Errors due to misalignment are made manifest by small discrepancies between check samples and STD record when salinity is low and/or temperature is high, expanding to large discrepancies when salinity is high and/or temperature is low.

It is readily seen that this phenomenon could seriously affect interpretations of STD data. For instance, in the case of a subsurface lowering, with a check sample obtained only at the surface, the ordinary reconciliation might not take into account the possibility of an increasing anomaly as the instrument was lowered through colder and more saline water. Lack of accuracy of the data offsets the advantage and convenience of the STD for rapid surveying if discrepancies are large. It is extremely important that, once the instrument is calibrated, adjustments at sea be kept at a minimum and then only with great care. In the light of the following considerations and formulae, the STD instrument and its computing circuit has proven most accurate.

CHARACTERISTIC ERROR OF THE STD

The first consideration will be to show the relation which may appear between a titrated salinity sample and the recorded salinity as computed by the instrument. The empirical formula for the salinity computing circuit is

$$S = \frac{100{,}000}{25.661 + 0.73720T} - 348.87\ C^{1.0916} \qquad (1)$$

where S is salinity in parts per thousand, T the temperature in degrees Fahrenheit, C is specific conductance in mhos per centimeter cube (Jacobson, 1948). The formula is an approximation designed to give the least amount of error in ranges of salinity from 30 °/oo to 35 °/oo.

If sea water of a certain salinity and temperature is being measured by the instrument, conductivity of the sample must also be a certain value. Any error in the computed salinity, aside from some constant calibration error, will depend upon an error in temperature, assuming no change in conductivity. Thus,

$$\frac{dS}{dT} = - \frac{73720 \; C^{1.0916}}{(.73720T + 25.661)^2}$$

or, approx.

$$\Delta S = - \frac{73720 \; C^{1.0916} \; \Delta T}{(.73720T + 25.661)^2} \qquad (2)$$

The error in salinity, ΔS is proportional to the temperature error, ΔT.

Substituting for $C^{1.0916}$ in (2)

$$\Delta S = - \frac{73720 \; S \; \Delta T}{2{,}336{,}373.75 + 60520.66T - 189.60T^2}$$

which can be simplified to approximately

$$\Delta S = \frac{389 \; S \; \Delta T}{(T - 354)(T + 35)} \qquad (3)$$

The error in salinity is proportional to the true salinity, S, and is inversely related to temperature, T.

The salinity error can be serious if the computing temperature differs from the real temperature by only a small amount. The following table shows some calculations for ΔS for several salinities and temperatures based on an instrumental error of 1°F.

	35 ‰	30 ‰	25 ‰	Salinity
80°F.	0.43	0.37	0.31	
50°	0.53	0.45	0.38	
30°	0.65	0.55	0.46	

If the accuracy of the instrument is assumed to be comparable to that of titrated samples, the table above has real significance. To be comparable to titrated values, temperature must not be in error by more than 0.1°F. (the tabulated ΔS divided by 10). Even if the recorded temperature is reasonably accurate, it can be linked erroneously with the computing circuit; consequently, ΔT can be a large value without the observer being aware of the difficulty. Consequently, the greater the ΔT, the greater, also, will be the apparent randomness of the salinity error, as shown by the table and equation (3)*.

Since equation (3) requires simultaneous knowledge of the salinity error and temperature error to determine the true salinity of an observation, it is not adequate, except as a check, for reconciling STD data. The following discussion will attempt to develop an empirical method for the correction of STD data.

EMPIRICAL FORMULA FOR CORRECTING STD DATA

In the three coordinate system let $x = S_r$, the <u>recorded</u> salinity resulting from instrumental computation, with the condition that at $x = 0$,

$$S_r = 0 \text{ and } S = 0.$$

The difference, $S_r - S = \Delta S$, will be taken vertically along the y axis (as shown in Fig. 1). For a given temperature, T, the relation, $\frac{\Delta S}{S}$, will be constant for a <u>constant temperature error</u>, ΔT, in the computing circuit. Also, the ratio

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* The accuracy of the STD is claimed to be within 0.3 ‰. The successful use of this method of correction in over a thousand stations suggests that the accuracy of the STD is much better than above. Indeed, it is possible that such latitude in the probable salinity error is due to inherent sensitivity in the calibration of the instrument and inadequate procedures for maintenance at sea.

$$\frac{\Delta S}{S + \Delta S} = \frac{\Delta S}{S_r} = \tan \theta = k$$

Consequently,

$$\Delta S_n = kS_{r_n}$$

Or

$$\Delta S_n = \frac{S_{r_n}}{S_{r_o}} \cdot k \cdot S_{r_o}$$

If S_{r_o} is used as a reference, for a set of data with a constant temperature error,

$$\Delta S_n = A \frac{S_{r_n}}{S_{r_o}}$$

for a given temperature, T_{r_o}.

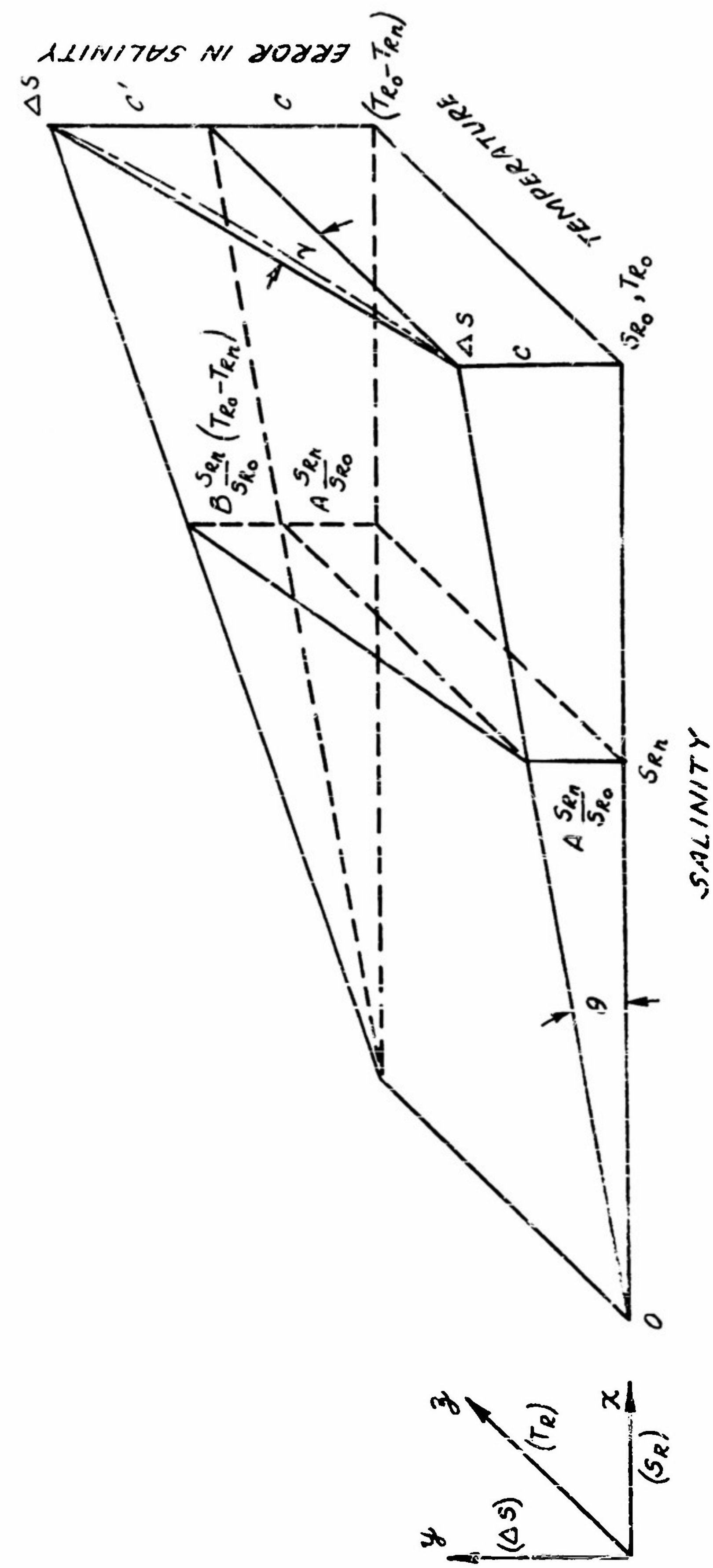
On the z axis let $z = T_{r_o} - T_{r_n}$ where T_{r_o} is any temperature <u>recorded</u> by the STD, suitable for reference. The point $z = 0$, $y = \Delta S$, $x = S_{r_o}$ applies to a known error of a <u>recorded</u> salinity at a particular temperature. If we assume that the temperature circuit is in good working order, ΔT is a constant error in the computing circuit and $T_r \cong T$. From equation (3), ΔS is nearly inversely proportional to T_r, the <u>recorded</u> temperature, or, T, in the ranges 30° to 80°F.

Therefore, as temperature decreases from T_{r_o}, ΔS will increase. ΔS at $T_{r_o} - T_{r_n}$ will differ from ΔS at T_{r_o}, C, by an amount, C' and

$$C' = (T_{r_o} - T_{r_n}) \tan \gamma \qquad \text{(Figure 1)}$$

Let

$$C = \Delta S - C' = A \frac{S_{r_n}}{S_{r_o}}$$



ERROR IN SALINITY
TEMPERATURE
SALINITY
ΔS
C'
C
$(T_{Ro} - T_{Rn})$
S_{Ro}, T_{Ro}
S_{Rn}
$B \frac{S_{Rn}}{S_{Ro}} (T_{Ro} - T_{Rn})$
$A \frac{S_{Rn}}{S_{Ro}}$
γ
θ
0
x (S_R)
y (ΔS)
z (T_R)

FIG. 1

Without formal proof

$$\tan \nu = \ell S_r \tan \theta$$

where ℓ is a constant and $\tan \theta = \frac{C}{S_{r_o}}$ at T_{r_o}.

By substitution, then

$$\frac{C'}{T_{r_o} - T_{r_n}} = \ell C$$

Or

$$C' = \ell C \, (T_{r_o} - T_{r_n})$$

and C' is proportional to C for any constant temperature.

Since

$$C = A \frac{S_{r_n}}{S_{r_o}}$$

Then

$$C' = \ell A \frac{S_{r_n}}{S_{r_o}} \, (T_{r_o} - T_{r_n})$$

Combining,

$$C + C' = \Delta S$$

$$\Delta S = \frac{S_{r_n}}{S_{r_o}} \left[A + B \, (T_{r_o} - T_{r_n}) \right] \qquad (4)$$

where $B = \ell A$.

It is readily seen that as long as a reference S_r is maintained, the formula, (4), can be transposed to the proven formula, $C = \Delta S$, by substituting T_{r_n} for T_{r_o}.

For a set of STD data in which there are a number of calibration samples, formula (4) becomes

$$\Delta S = \frac{S_r}{\overline{S_r}} \overline{\Delta S} + B\,(\overline{T_r} - T_r)$$

Where $\overline{S_r} = S_{r_o}$, the average S_r for which there are samples, $\overline{T_r} = T_{r_o}$, the average T_r of the same samples, $\overline{\Delta S} = A$, the average deviation of S_r from S in the set of data. Once B is known, ΔS can be solved for any pair of values, S_r and T_r.

B is solved for in the equation

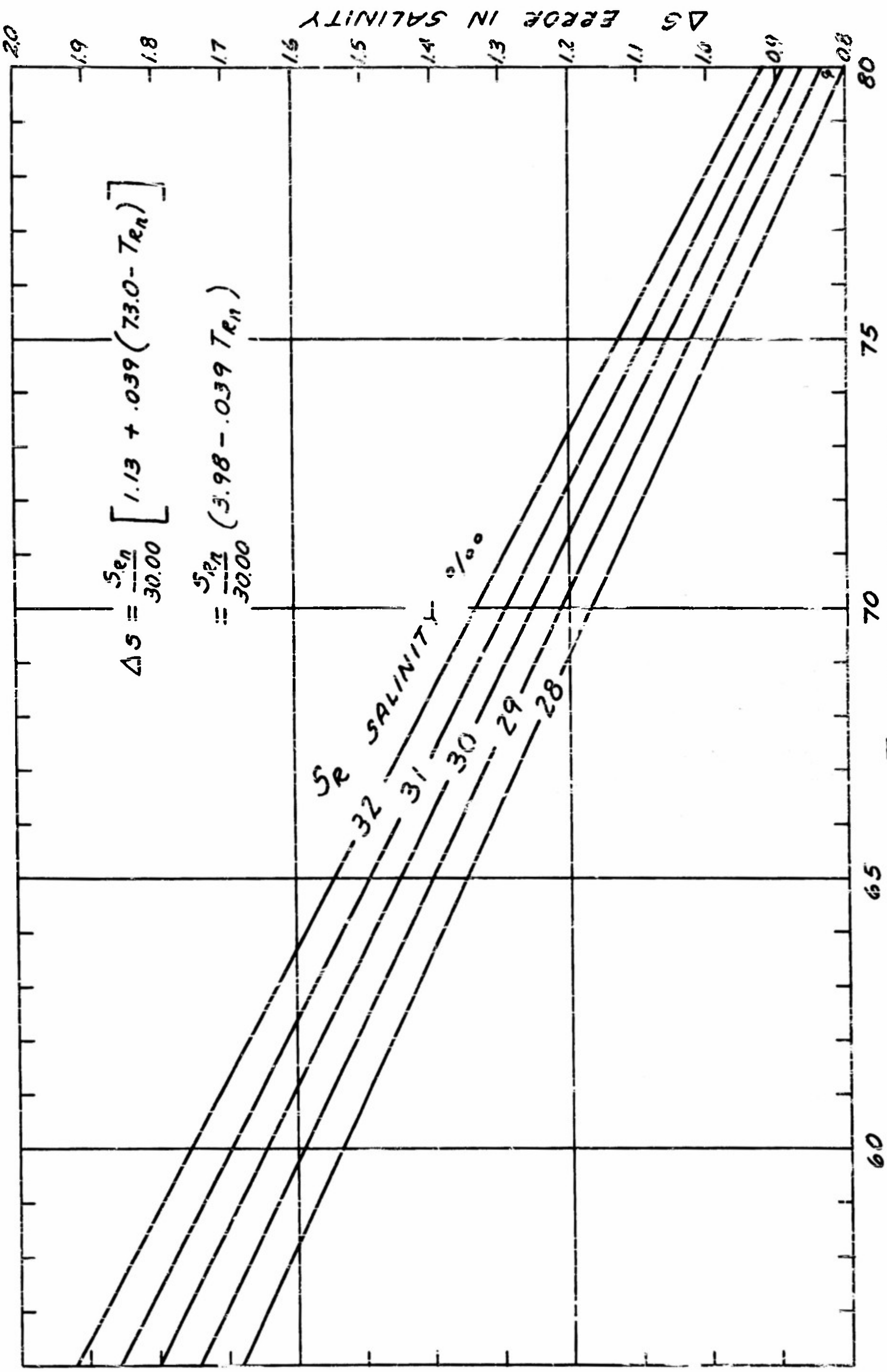
$$B = \sum \left(\frac{\dfrac{\Delta S_n \, \overline{S_r}}{S_{r_n}} - \overline{\Delta S}}{\overline{T_r} - T_{r_n}} \right) /n$$

Ideally, there should be no difficulty solving for B, but the sensitivity of the computing circuit to temperature is such that the accuracy needed to check the STD data is scarcely attainable at sea. For the most part, individual calculations of B are reasonably constant, except for $T_{r_o} - T_{r_n} < 1°$, or, obviously inadequate sampling. The latter cases should not be included in the averaging of B. With the completion of the equation, it is a simple matter to construct a nomogram (Fig. 2) for the range of values in the set of data and to apply the indicated corrections.

The validity of the calculations is dependent on the accuracy, number and range of the checking samples. If a hidden constant calibration error is included in the calculations, the accuracy of the formula is affected percentagewise. It is a matter of judgment whether to apply the formula or not, depending on the apparent randomness of the error.

REFERENCE

Jacobson, A. W., 1948: An instrument for recording continuously the salinity, temperature and depth of sea water. <u>Trans. Amer. Inst. Elect. Engrs.</u>, <u>67</u>: 714-722.



ΔS ERROR IN SALINITY
$\Delta S = \frac{S_{R_n}}{30.00}\left[1.13 + .039\,(73.0 - T_{R_n})\right]$
$= \frac{S_{R_n}}{30.00}\,(3.98 - .039\,T_{R_n})$
S_R SALINITY ‰
32
31
30
29
28
T_R TEMPERATURE °F

FIG.2

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